NUMERICAL STUDY OF ROUGH SURFACE SCATTERING

Eric I. Thorsos
Applied Physics Laboratory
College of Ocean and Fishery Sciences
University of Washington
Seattle, Washington 98105
phone: (206) 543-1369 fax: (206) 543-6785 email: eit@apl.washington.edu
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High-Frequency Acoustics

LONG-TERM GOAL

To improve our understanding of acoustic scattering from rough surfaces, with applications to scattering from both the sea bottom and the sea surface.

SCIENTIFIC OBJECTIVES

Improve our understanding of the effects of the rough interface on acoustic penetration into sediments at low grazing angles, and determine the accuracy of theoretical approaches, such as perturbation theory, for describing this process. Develop theoretical and numerical methods for
accurately treating bistatic scattering from rough surfaces at low grazing angles.

APPROACH

Acoustic penetration of high frequency sound into sediments is necessary for acoustic detection of buried mines. For sandy sediments the sound speed is higher in the sediment than in the water, resulting in a critical angle of about 25-30. For grazing angles below the critical angle, acoustic energy will not penetrate beyond a thin evanescent region, assuming the sediment can be represented simply as a fluid, and assuming the water-sediment interface can be approximated as flat. It is important to understand if significant subcritical penetration is possible, since it would allow lower grazing angles, and hence longer ranges to be used for buried mine detection. In particular, roughness at the water-sediment interface will couple acoustic energy into the sediment at angles below the classical critical angle. For examining the efficiency of coupling by roughness, the sediment is modeled as an attenuating fluid. An exact integral equation is solved numerically to obtain the penetrating field in two dimensions. These results yield insights on acoustic penetration into sediments due to interface roughness. Exact results are also used to examine the accuracy of scattering theory for both bottom and surface scattering.

WORK COMPLETED

In collaboration with Jackson and Williams, simulations of experimental measurements (Chotiros, 1995) of acoustic fields penetrating sediments were made based on perturbation

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theory to account for the effects of sediment roughness. Exact integral equation simulations were also done to verify that perturbation theory is accurate for the cases considered.

Integral equation simulations for scattering from rough two-fluid interfaces have been carried out for making detailed comparisons with results obtained by Hastings, Schneider, and Broschat at WSU using the finite difference time domain method. This work is continuing.

A report on the High-Frequency Acoustics Workshop held in April 1996 was completed and distributed. This report contains a discussion of high-frequency acoustics issues.

RESULTS

Simulations of acoustic measurements showed that scattering from roughness at the water-sediment interface can explain the results obtained by Chotiros (1995) with a suitable choice of roughness spectrum. Chotiros observed sound penetrating into sandy sediments when the incident grazing angle was below the critical angle, and the propagation speed in the sediment was inferred to be near 1200 m/s, significantly lower than the compressional sound speed of about 1700 m/s in unconsolidated sands. Chotiros interprets these results to indicate the excitation of a Biot slow wave in the sediment. Our simulations of these measurements (Thorsos, Jackson, Moe, and Williams, 1997), based on scattering by roughness, yield sound penetration into the sediments with apparent propagation speeds less than the true compressional sound speed in the sediment. The apparent speed is that inferred from a processing algorithm similar to that used by Chotiros with the experimental data. The roughness spectrum was not measured and assumed forms were used for the simulations. If a low-wavenumber cutoff is used to produce a spectrum relatively rich in high-wavenumber components, apparent speeds in the 1100-1300 m/s range can be obtained, in agreement with experimental results. If a typical power-law form is used, an apparent speed of about 1500 m/s is obtained.

IMPACT/ APPLICATIONS

The results of the bottom scattering work are relevant to the detection of buried mines using high frequency acoustics at low grazing angles.

RELATED PROJECTS

This work is directly related to the ONR DRI "High-Frequency Sound Interaction in Ocean Sediments" beginning in FY98. Close coordination is maintained with the ONR projects of Darrell Jackson, Kevin Williams, and Dajun Tang in problems of bottom scattering and penetration.

REFERENCES

N. P. Chotiros. 1995. "Biot model of sound propagation in water-saturated sand," J. Acoust. Soc. Am., Vol. 97, 199-214.

E. I. Thorsos, D. R. Jackson, J. E. Moe, and K. L. Williams. 1997. "Modeling of subcritical penetration into sediments due to interface roughness," Proceedings of the High Frequency Acoustics in Shallow Water Conference, Lerici, Italy, pp. 563-569.